Proximate, Functional and Pasting Properties of Composite Flours Made from Cassava, Bambara Groundnut and Cashew Kernel

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Abstract*: - This study investigated the quality of composite flour from cassava, bambara groundnut and cashew seeds. Cassava was processed using high quality method, bambara groundnut was toasted while cashew nuts was roasted. Composite flours were formulated using design expert software for mixtures. The design matrix revealed fourteen formulations. The proximate composition, pasting properties and functional properties were evaluated as a function of the flour blends. Standard method of analysis was used. Statistical analysis using an analysis of variance (ANOVA) technique ($P \leq 0.05$) showed that there were significant differences in most of the parameters analyzed for the process variables. The range of the proximate compositions determined were: moisture (7.44-9.43%), protein (1.69-24.25 %), crude fat (0.71-32.33 %), crude fibre (0.81-3.48%), total ash (0.42-4.00%), and carbohydrate (30.10-89.04%) and energy (368.82 – 509.23 %). The protein, fat, ash and crude fibre content of the flour blends increased relatively with inclusion of cashew kernel flour whilst the moisture and carbohydrate contents decreased. Bulk densities of composite flour samples ranged from 0.55 – 0.81 g/ml, water absorption capacity (WAC) and Oil absorption capacity (OAC) of composite flours ranged from 99.07 – 150 %, 118.23 – 184.35% respectively. The WAC increased with increasing cassava flour substitution. Peak viscosity (249.01 RVU), trough viscosity (218.17 RVU) and final viscosity (368.33 RVU) were highest at cassava flour substitution. Fortification of tuber flours with leguminous and nut flours will enhance food availability and security.

***Keywords:* Bambara groundnut, Composite flour, Flour formulation, Pasting properties, Proximate properties.**

I. INTRODUCTION

Composite flour is made by blending or mixing varying proportion of more than one non-wheat flour with or without wheat flour and used for production of leavened or unleavened baked or snack products that are traditionally made from wheat flour and increase the essential nutrients in human diet composite flour (Chandra *et al*., 2015).

Cassava or manioc is a woody shrub of the *Euphorbiaceous* (Spurge) family; native to South America and extensively cultivated as an annual crop in tropical and sub- tropical regions for its edible starchy tuberous root, a major source of carbohydrates. (Nassar *et al*., 2008). The root crop is a source of livelihood for at least 300 million people. Virtually all cassava (90%) produced in Africa is used as a staple food for human consumption, providing calories for ~500 million people and constituting ~37% of the population's dietary energy requirements (Sanginga (IITA), 2015) .

Bambara (also spelt Bambarra) groundnut originated in West Africa and still a traditional food plant in Africa (FAO Statistical Database (FAOSTAT), 2011). As an indigenous tropical crop, bambara groundnut is cultivated in Nigeria. It is grown in areas such as Enugu state, many northern states and some parts of South West Nigeria (Fasoyiro *et al*., 2006). Bambara is a very important crop, but it is not a lucrative cash crop despite being the third most important legume in much of Africa (De Kock, n.d) after peanuts and cowpeas. The seed is a balanced food because when compared to most food legumes, it is rich in iron, the protein contains high lysine and methionine (Adu-Dapaah and Sangwan, 2004).

Cashew is one of the most important crops in tropical regions, it occupies an area around 3.39 million hectares in the world. Its main economics products are the kernel and the cashew nut shell liquid (CNSL) (Oliveira, 2008). Several studies have done on cashew plant. All these efforts are aimed at reducing the wastage of cashew in Nigeria and the use of its by-products (cashew-apple residue and cashew nut flour) as functional ingredients.

Effective processing and utilization of flour blends of locally grown crops based on nutrient complementary will be one of the ways of addressing the world food problem and insecurity. This will also help to combat the high rate of post harvest losses experienced in the country (Elochukwu and Iwuoha, 2015). The objective of this work was to determine the proximate composition, pasting properties and functional properties of the flour mixtures in order to obtain the optimum ratio of high nutrient quality for food production.

II. MATERIALS AND METHODS

2.1 Material

Cassava tubers were processed using the high-grade processing method for cassava flours as described by Oti and Ukpabi (2006). Toasted bambara groundnut flour was processed using the method described by Elochukwu *et al.*

(2019). Cashew kernel flour was processed using the method described by Okafor and Ugwu (2014).

2.2 Flour blend formulation

A three-component augmented simplex lattice design as described by Myers *et al*. (2009) was used for the flour blend. The three mixture components evaluated in this study were cassava flour (X_1), toasted bambara groundnut flour(X_2) and roasted cashew kernel flour (X_3). The proportions for each ingredient represents a fraction of the mixture and for each treatment combination, the sum of the component proportions was equal to one i.e.

$$\sum X_i = X_1 + X_2 + X_3 = 1$$

This design resulted in 10 flour mixtures and four replications (Table 1).

Table 1: Experimental design used to produce flour blends

Blends	High quality cassava Flour (HQCF) (%)	Toasted bambara groundnut flour (TBF) (%)	Cashew kernel flour (CKF) (%)
1	0	100	0
2	100	0	0
3	50	0	50
4	0	0	100
5	100	0	0
6	50	50	0
7	50	50	0
8	0	0	100
9	0	50	50
10	0	100	0
11	33.3	33.3	33.3
12	16.7	66.6	16.7
13	66.6	16.7	16.7
14	16.7	16.7	66.6

2.3 Proximate analysis of data

The moisture, crude fat, ash, crude fibre, carbohydrate content, dry matter and energy contents were determined by the method of AOAC (2005).

2.4 Statistical Analysis

Data were collected on triplicate determinations and means ± standard deviations (SD) were computed. These data were analyzed using analysis of variance (ANOVA) as described by Nwachukwu and Egbulonu (2000). Mean separation was done using the F- LSD to determine the significant differences at 5% level.

III. RESULTS AND DISCUSSION

3.1 Mean proximate composition of high quality cassava, toasted bambara groundnut and roasted cashew kernel flour blends

Table 2 shows the result of the proximate composition of the flour blends. Moisture content of the flour blends ranged from 5.98 % - 9.43 %. The highest moisture content was recorded in blend 12 (representing 16.7% cassava flour, 66.6% bambara groundnut flour and 16.7% cashew kernel flour) while the lowest moisture content was recorded in blend 8 (representing 0% cassava flour, 0% bambara groundnut flour and 100% cashew kernel flour) . The least moisture content was that of 100% cashew kernel flour (5.98 %). The results suggest that the flour blend can keep for a long period especially if stored in airtight packaging materials of low air and moisture permeability. However, all the flour blends fell below 10% maximum recommended by Standard Organization of Nigeria (SON) (Sanni *et al.* 2005). There were no significant differences ($p>0.05$) between blend 6, 13, 14 and blend 1 and 9 respectively.

The protein content of the flour blends increased relatively because of inclusion of the roasted cashew kernel flour; the higher the level of roasted cashew kernel flour, the higher the level of protein in flour blends relatively. The level of protein observed ranged from 1.69 % – 24.25 % for flour blends of 2 and 4 (representing 100% cassava flour, 0% bambara groundnut flour and 0% cashew kernel flour) and (0% cassava flour, 0% bambara groundnut flour and 100% cashew kernel flour) respectively. Protein content of all the flour blends differed significantly ($p<0.05$).

The fat content of the flour blends increased relatively because of inclusion of the cashew kernel flour; the higher the level of cashew kernel flour, the higher the level of fat in the flour blends relatively. The level of fat observed ranged from 0.71 % – 32.33 % for the flour blends. The highest fat content (32 %) was in flour blend 8 (representing 0% cassava flour, 0% bambara groundnut flour, 100% cashew kernel flour) and this was significantly different($p<0.05$) from the other blends. The least fat content (0.71 %) was in flour blend 5 (100% cassava flour, 0% bambara groundnut flour and 0% cashew kernel flour) (Table 2). There were significant differences ($p<0.05$) in the fat content of the flour blends except for blend 2 and 5 (representing 100% cassava, 0% bambara groundnut, 0% cashew kernel flour)..

The crude fibre content of the flour blends ranged from 0.81 – 3.48 %. The least crude fibre content (0.81 %) was recorded in blend 2 (representing 100% cassava, 0% bambara groundnut, 0% cashew kernel flour) while the highest value (3.48 %) was recorded for blend 4 (representing 0 % cassava, 0 % bambara groundnut and 100% cashew kernel flour). There were significant differences ($p<0.05$) in the fibre content of the flour blends except for blend 6 and 7 and blend 1 and 11. This observation suggests that the any product produced with this flour blend 4 and 8 would provide good dietary fibre in the diet. This is an indication that cashew kernel flour can be incorporated in the formulation of pastry products. Ebere *et al*. (2015) reported an increase in fibre content of cookies formulated from the blends of wheat/cashew apple residue up to 9.4 % with 20 % incorporation.

The ash content of the flour blend samples ranged from 0.42 % - 4.00 %. The highest ash content was observed in blend 4 (representing 0% cassava flour, 0% bambara groundnut flour and 100% cashew kernel flour) while the least value was in blend 5 (100% cassava,0% bambara groundnut flour and 0% cashew kernel flour) respectively. There were increases in the ash content in all the samples where the quantity of roasted cashew kernel flour was higher (Table 2). This shows that the addition of cashew kernel flour may have caused increases in the ash content. According to Camire (2000), the level of ash in food is an important nutritional indicator of mineral density. There were significant differences ($p<0.05$) in all the flour blends except for blend 12 and 13 where there are no significant difference ($p>0.05$).

The carbohydrate content of the flour blends varied with increase in cassava flour (Table 2). The value ranged from 30.10 % - 88.98 % for blends of 4 (representing 0% cassava flour, 0% bambara groundnut flour and 100% cashew kernel flour) and blend 5 (100% cassava flour, 0% bambara groundnut flour and 0% cashew kernel flour) respectively. The least value obtained for carbohydrate (by difference) was 30.10 % for blend 4 (0% cassava flour, 0% bambara groundnut flour and 100% cashew kernel flour).

The energy content of the flour blends ranged from 368.82 kcal/100g to 509.23 kcal/100g (Table 2). The highest energy content was recorded in blend 8 (representing 0% cassava flour, 0% bambara groundnut flour and 100% cashew kernel flour) while the least energy value was recorded in blend 2 and 5 (representing 100% cassava flour, 0 % bambara groundnut flour and 0 % cashew kernel flour). The flour blends with the highest energy values could be because of the high levels of crude fat and crude protein in the flour blends. The high-calculated energy value (509.23 kcal/100g) showed that cashew kernel flour is a concentrated source of energy capable of supplying the daily energy requirements of the body. All the energy vales of the flour blends differed significantly ($p<0.05$) except for blend 2 and 5 (representing 100% cassava flour, 0 % bambara groundnut flour and 0 % cashew kernel flour).

3.2 Mean pasting Properties of high quality cassava, toasted bambara groundnut and roasted cashew kernel flour blends

Peak viscosity is the maximum viscosity developed during or after the heating period of a test sample. Ikegwu *et* al. (2009) reported that peak viscosity is a reflection of the ability of starch to swell freely before their physical breakdown. High peak viscosity (PV) indicates high swelling power and corresponds to high thickening power of the samples starch (Kin Kabiri *et al*., 2015). Peak viscosity relates to the final product quality. The highest peak viscosity were obtained in blends 2 and 5 (100% cassava, 0% bambara groundnut flour and 0% cashew kernel flour) 249.00 RVU and 249.01 RVU respectively while the least peak viscosity was obtained from blend 11 (32.00 RVU) (33.3% cassava,33.3% bambara groundnut flour and 33.3% cashew kernel flour) (Table 3). This indicates that the flour blends 2 and 5 have high swelling power than the other flour blends samples and could be used as food thickeners because of its index of high starch content. Peak viscosity is closely associated with the degree of starch damage and high starch damage results in high peak viscosity (Sanni *et al*., 2001). This variation in the peak viscosity could be because of the amylose contents of the flour samples (Oledinma *et al*., 2009). High peak viscosity is an indication of the suitability of the blends for products requiring high gel strength and elasticity. The peak viscosity increased with the increasing level of cassava substitution. This increase may be attributed to the high starch of cassava flour causing high gelatinization and swelling index.

Table 3 indicates that blends 2 and 5 (100% cassava, 0% bambara groundnut flour and 0% cashew kernel flour) had the highest trough viscosity (218.17 RVU) while the least trough value was blend 11 (27.67 RVU) (33.3% cassava, 33.3% bambara groundnut flour and 33.3% cashew nut flour). Trough viscosity (TV) is the minimum viscosity value, which measures the ability of paste to withstand breakdown during cooling. This indicates that the paste of blend 2 and 5 can stand firm during cooling without breaking easily while blend 11 will easily breakdown during cooling.. There were significant differences ($p<0.05$) among the flour blends.

Breakdown viscosity is a measure of degree of starch disintegration or the hot paste stability of the starch. Lower breakdown viscosity indicated higher paste stability (Bakare *et al.*, 2015). Flour blend 1 and 10 (0% cassava, 100% bambara groundnut flour and 0% cashew kernel flour) had the least breakdown viscosity (0.59 RVU and 0.60 RVU) (Table 2). This could be as a result of the higher content of bambara groundnut and this corresponds with the work of Awolu and Oseyemi (2016) which stated that cocoyam-based composite flour (CBC1) had the least breakdown viscosity as a result of the higher content of bambara groundnut (a legume) present. A low breakdown value however suggests the stability of starches under hot conditions. Adebowale *et al*. (2005) reported that the higher the breakdown viscosity, the lower the ability of the flour to withstand heating and shear stress during cooking. Table 3 also indicates that the highest breakdown viscosity (61.35 RVU) was obtained from blend 13 (66.6% cassava, 16.7% bambara groundnut flour and 16.7% cashew kernel flour). Chinma *et al*. (2010) also reported that high breakdown value indicates relative weakness of the swollen starch granules against hot shearing while low breakdown values indicate that the starch in question possesses cross-linking properties. There were significant differences ($p<0.05$) among the flour blend samples for break down viscosity.

There were significant differences ($p< 0.05$) among the flour samples for final viscosity and setback. The final viscosity and setback viscosity increased with an increase in substitution of the cassava flour (Table 3). Final viscosities are important in determining the ability of the flour sample to form gel during processing while set back viscosity indicates gel stability and potential for retrogradation (Niba *et al*., 2001). Chinma *et al.* (2010) also reported that high setback value is an indication of the propensity of the starch molecules to disperse in hot paste and re-associate readily during cooling. During cooling, re-association between starch molecules especially amylose will result in the formation of a gel structure and therefore the viscosity will increase to a final viscosity (Ragaae *et al*., 2006). The final viscosity of the blend 2 and 5 (100 % cassava flour: 0 % bambara groundnut flour: 0 % cashew kernel flour) recorded the highest value of 368.33 RVU and while the lowest value of 70.92 RVU was recorded for blend 13 (33.3% cassava flour: 33.3% bambara groundnut flour: 33.3% cashew kernel flour). This indicates that the flour samples from blend 2 and 5 with higher final viscosity will form firmer gel after cooking and cooling. The final viscosity is the most commonly used parameter to determine a particular sample quality and indicates the stability to form various paste or gel after cooling (Ikegwu *et al*., 2010).

Peak time is a measure of the cooking time and this ranged from 6.25 min to 7.00 min while pasting temperature value ranged from 81.46˚C to 94.12˚C. The attainment of the pasting temperature is essential in ensuring swelling, gelatinization and subsequent gel formation during processing. The pasting temperature (PT) is the temperature at which the viscosity starts to rise (Liang and King, 2003). Table 3 reveals that flour blend 14 (16.7 % cassava flour: 16.7 % bambara groundnut flour: 66.6% cashew kernel flour) had the highest pasting temperature with the equivalent highest peak time and was significantly different ($p<0.05$) from the other blends.

3.3 Mean Functional Properties of high quality cassava, toasted bambara groundnut and roasted cashew kernel flour blends

The result obtained for water absorption capacity ranged from 110.83 % to 150.74 % (Table 4). Water absorption capacity is the ability of flour to absorb water and swell for improved consistency in food (Osundahunsi *et al*., 2003). The water absorption capacity of blends 2 and 5 (100% cassava, 0% bambara groundnut and 100% cashew kernel flour) were significantly higher ($p < 0.05$) than other blend samples (Table 4) .This characteristic make it suitable for energy bar production since high WAC improves yield and consistency and also gives body to the food products. High water absorption capacity in some of the flour blends indicates its usefulness in bakery products as this could prevent staling by reducing moisture loss (Okpala and Chinyelu, 2011) and helps to maintain the freshness of bread, cakes and sausages. Water absorption capacity of flour enables the processor to add more water during food preparation thereby improving handling characteristics and their use as a soup thickener (Falade and Okafor, 2014). It is clear that the WAC and OAC of the composite flours increased with increase in the proportion of cassava flour as reported by Iwe *et al*. (2017). This is an indication that blend 2 and 5 could be a good retainer of flavor and could also give a better mouth feel when used in the snack bar preparation.

The swelling power which is the measure of the ability of starch to imbibe water and swell or the extent of granule swelling in the various flour blends ranged from 8.46 to 18.26 g/g . Blend 2 and 5 (100% cassava, 0% bambara groundnut and 0% cashew kernel flour) were significantly ($p<0.05$) higher than other flour blends. According to Table 3, these blends (2 and 5) also had the highest peak viscosities. This confirms the relationship between swelling power and peak viscosity. Aryee *et al*. (2006) reported the swelling power of the cassava flour samples to be from 5.87 % to 13.48 %. The values obtained from this study were higher than the report of Aryee *et al*. (2006). Moorthy (2002) reported that highly associated starch granules display a greater resistance towards swelling, owing to an extensive and strongly bonding micelle structure, which affects the firm forming capability of starch. Blend 4 and 8 (0% cassava, 0% bambara groundnut flour and 100% cashew kernel flour) had the least carbohydrate content and the least swelling power (8.46 g/g) ..

The bulk density of the flour samples were between 0.55 g/ml to 0.81 g/ml. Blends 4 and 8 (0% cassava, 0% bambara groundnut and 100% cashew nut flour) were significantly higher ($p < 0.05$) than other blend samples. Blend 1 and 10 (0% cassava, 100% bambara groundnut and 0% cashew kernel flour) had the least value (0.55 g/ml). The change in bulk density is dependent on the density of the flour. Bulk density is a measure of heaviness of solid samples, which is important for determining packaging requirements, material handling and application in the food industry. Akubor and Badifu, (2004) states that flours with high bulk densities (>0.7 g/cm^3) are used as thickeners in food products. Incorporation of bambara groundnut flour reduced the bulk densities of the flour samples.

The oil absorption capacity (OAC) ranged from 118.73 to 184.35 % among all the flour blends. Blend 2 (100% cassava flour, 0% bambara groundnut flour and 0% cashew kernel flour) had the highest OAC while blend 10 (0 % cassava flour, 100 % bambara groundnut flour and 0 % cashew nut flour) had the least OAC (Table 3). The OAC was found to be insignificant ($p>0.05$) in the same flour samples. The major chemical component affecting OAC is protein, which is composed of both hydrophilic and hydrophobic parts. Non-polar amino acid side chains can form hydrophobic interaction with hydrocarbon chains of lipids (Jitngarmkusol *et al*., 2008). The higher OAC of the HQCFs compared to composite flours could also be an indication of higher polar amino acid residues of proteins having an affinity for oil molecules.

Emulsion capacity (EC) is the ability of flour to emulsify oil (Okpala and Chinyelu, 2011). The emulsion capacities of the flour blends ranged from 18.57 % to 46.37 % (Table 4). Blend 5 (100% cassava, 0% bambara groundnut and 0% cashew kernel flour) was significantly higher ($p < 0.05$) from other flour samples and had the highest emulsion capacity (46.365 %). This is in agreement with the emulsion capacity of high quality cassava flour (42.74 %) as reported by Adebowale *et al*., (2011). The least emulsion was obtained in blend 4 and 8 (0% cassava, 0% bambara groundnut and 100% cashew kernel flour) (18.57%). High emulsion capacity is indications that a flour sample could be an excellent emulsifier. Emulsifiers are incorporated into cookie formula to improve dough handling and the product's overall quality (Hoque *et al*., 2009). This showed that blend 2 and 5 will make good emulsifiers.

IV. CONCLUSION

The study revealed that the flours of cassava, bambara groundnut and cashew kernel flours will enhance the nutritional content of the products derived from them. Hence, it is an ideal source of promoting the dietary protein for human consumption. The blending of the flours reveal a decrease in the carbohydrate content of the blend ratios with increase in the substitution levels of the cashew kernel flours. Fortification of tuber flours with leguminous flours and nuts will enhance food availability. This will help achieve one of the major goals of food security.

Table 2: Proximate composition of high quality cassava, toasted bambara groundnut and roasted cashew kernel flour blends

Blends	Independent variables			Proximate composition (%)						
	X_1	X_2	X_3	Moisture	Protein	Fat	Fibre	Ash	CHO	Calorie (kcal/100g)
1	0	100	0	8.68^{e}	17.87^{d}	7.73^{g}	1.82^{f}	1.91^{d}	63.17^{e}	393.72^{f}
2	100	0	0	7.44^{h}	1.69^{h}	0.72^{k}	0.81^{j}	0.42^{h}	88.92^{a}	368.93^{j}
3	50	0	50	8.20^{f}	10.32^{f}	9.89^{e}	1.93^{e}	1.50^{f}	68.16^{d}	402.93^{e}
4	0	0	100	6.50^{i}	24.25^{a}	31.07^{b}	3.48^{a}	4.00a	30.10^{j}	502.43^{b}
5	100	0	0	7.44^{h}	1.57^{h}	0.71^{k}	0.83^{j}	0.42^{h}	89.04^{a}	368.82^{j}
6	50	50	0	9.00^{c}	10.44^{f}	4.00^{j}	1.35^{hi}	1.11^{g}	74.10^{c}	374.15^{i}
7	50	50	0	9.29^{b}	9.68^{f}	4.80^{i}	1.39^{h}	1.76^{de}	73.08^{c}	374.24^{i}
8	0	0	100	5.98^{j}	20.26^{b}	32.33^{a}	3.38^{b}	3.75^{a}	34.30^{i}	509.23^{a}
9	0	50	50	8.69^{e}	18.67^{cd}	16.00^{d}	2.52^{d}	2.96^{c}	49.96^{g}	418.52^{d}
10	0	100	0	7.75^{g}	17.92^{d}	6.90^{h}	1.93^{e}	1.79^{de}	63.70^{e}	388.61^{g}
11	33.3	33.3	33.3	9.26^{b}	11.44^{e}	6.86^{h}	1.86^{ef}	3.26^{b}	67.32^{d}	376.78^{i}
12	16.7	66.6	16.7	9.43^{a}	18.58^{cd}	8.48^{f}	1.31^{i}	2.02^{d}	60.18^{f}	391.36^{fg}
13	66.6	16.7	16.7	9.05^{c}	5.38^{g}	6.48^{h}	1.70^{g}	1.68^{ef}	75.71^{b}	382.68^{h}
14	16.7	16.7	66.6	8.92^{d}	18.95^{c}	18.84^{c}	3.28^{c}	3.87^{a}	46.42^{h}	430.70^{c}
		LSD[1]		0.07	0.08	0.59	0.08	0.27	1.09	3.18

X_1 = Cassava flour (%), X_2 = bambara groundnut flour (%), X_3 = cashew kernel flour (%).CHO = Carbohydrate, Values are means of triplicate determinations. Experimental runs were randomized. LSD[1] Least significant difference at p=0.05. Means not followed by the same letter along the column are significantly different @ p<0.05.

Table 3: Pasting properties of high quality cassava, toasted bambara groundnut and roasted cashew kernel flour blends

Blends	Independent variables			Pasting parameter						
	X_1	X_2	X_3	Peak 1 viscosity^{b} (RVU)	Trough viscosity^{b} (RVU)	Break down viscosity^{b} (RVU)	Final viscosity^{b} (RVU)	Setback viscosity^{b} (RVU)	Peak Time(min.)	Pasting Temp (oC)
1	0	100	0	79.17^{g}	78.58^{e}	0.59^{j}	129.68^{f}	50.53^{g}	6.78^{c}	92.46^{f}
2	100	0	0	249.00^{a}	218.17^{a}	30.83^{d}	368.33^{a}	150.17^{a}	6.38h	93.35^{c}
3	50	0	50	165.30^{c}	108.08^{b}	57.22^{b}	236.42^{b}	71.12^{c}	6.58^{e}	92.65^{e}
4	0	0	100	34.67^{i}	30.42 ^{h}	4.25^{h}	84.08^{h}	53.67^{e}	6.42^{g}	81.46^{j}
5	100	0	0	249.01^{b}	218.17^{a}	30.83^{d}	368.33^{a}	150.17^{a}	6.38^{h}	93.35^{c}
6	50	50	0	108.58^{e}	67.67 ^{f}	40.92^{c}	170.08^{d}	102.42^{b}	6.48^{f}	91.45^{h}
7	50	50	0	108.58^{e}	67.67 ^{f}	40.92^{c}	170.08^{d}	102.42^{b}	6.48^{f}	91.45^{h}

8	0	0	100	34.67[i]	30.42 [h]	4.25[h]	84.08[h]	53.67[e]	6.42[g]	81.46[j]
9	0	50	50	37.83[h]	32.67[g]	5.17[f]	85.08[g]	52.42[f]	6.25[j]	85.12[i]
10	0	100	0	79.17[g]	78.58 [e]	0.59[j]	129.67[f]	50.50[h]	6.79[b]	92.46[f]
11	33.3	33.3	33.3	32.00[k]	27.67[j]	4.33[g]	70.92[j]	43.25[j]	7.00[a]	93.96[b]
12	16.7	66.6	16.7	98.50[f]	91.83 [d]	6.67e	131.17[e]	39.33[k]	6.66[d]	91.75[g]
13	66.6	16.7	16.7	161.92[d]	100.57[c]	61.35[a]	232.92[c]	71.00[d]	6.35i	92.85[d]
14	16.7	16.7	66.6	32.83[j]	29.17 [i]	3.67[i]	78.67[i]	49.50[i]	7.00[a]	94.12[a]
		LSD[1]		0.01	84.26	0.01	0.00	0.03	0.03	0.00

X_1 = Cassava flour (%), X_2 = bambara groundnut flour (%), X_3 = cashew nut flour (%), CHO = Carbohydrate, Values are means of triplicate determinations. Experimental runs were randomized. LSD[1] Least significant difference at p=0.05. Means not followed by the same letter along the column are significantly different @ p<0.05.[b]Viscosity measured in Rapid Visco-Analyser units (RVU), 1 RVU = 12 centipoise.

Table 4: Functional properties of high quality cassava, toasted bambara groundnut and roasted cashew kernel flour blends

Blends	Independent variables			Functional properties				
	X_1	X_2	X_3	WAC (%)	SWP (g/g)	BD(g/ml)	OAC (%)	EC (%)
1	0	100	0	118.43[e]	15.26[d]	0.55[j]	118.23[f]	27.46[e]
2	100	0	0	150.00[a]	18.26[a]	0.71[e]	184.35[a]	46.36[a]
3	50	0	50	109.87[g]	16.55[c]	0.73[d]	161.00[c]	38.57[c]
4	0	0	100	100.24[ij]	8.47[j]	0.81[a]	168.06[b]	18.57[j]
5	100	0	0	148.07[b]	18.26[a]	0.71[e]	182.33[a]	46.36[a]
6	50	50	0	121.03[d]	13.26[f]	0.58[i]	124.60[e]	21.14[g]
7	50	50	0	121.50[d]	13.26[f]	0.60[gh]	124.60[e]	21.15[g]
8	0	0	100	99.07[j]	8.46[j]	0.81[a]	163.02[c]	18.57[j]
9	0	50	50	101.20[i]	9.35[h]	0.65[f]	134.26[d]	19.36[i]
10	0	100	0	117.70[e]	15.27[d]	0.54[j]	118.73[f]	27.46[e]
11	33.3	33.3	33.3	107.79[h]	9.36[g]	0.63[g]	133.64[d]	26.25[f]
12	16.7	66.6	16.7	115.63[f]	14.26[e]	0.59[hi]	127.53[e]	30.22[d]
13	66.6	16.7	16.7	131.07[c]	17.36[b]	0.70[e]	167.47[b]	41.16[b]
14	16.7	16.7	66.6	100.43[i]	9.16[i]	0.79c	162.86[c]	19.76[h]
		LSD[1]		1.21	0.00	0.02	4.10	0.01

X_1 = Cassava flour (%), X_2 = bambara groundnut flour (%), X_3 = cashew kernel flour (%), CHO = Carbohydrate. Values are means of triplicate determinations.. Experimental runs were randomized. LSD[1] Least significant difference at p=0.05. Means not followed by the same letter along the column are significantly different @ p<0.05.

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